



Office de la Propriété  
Intellectuelle  
du Canada

Un organisme  
d'Industrie Canada

Canadian  
Intellectual Property  
Office

An agency of  
Industry Canada

CA 2211619 C 2002/01/29

(11)(21) 2 211 619

(12) BREVET CANADIEN  
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 1996/11/28  
(87) Date publication PCT/PCT Publication Date: 1997/06/05  
(45) Date de délivrance/Issue Date: 2002/01/29  
(85) Entrée phase nationale/National Entry: 1997/07/25  
(86) N° demande PCT/PCT Application No.: JP 1996/003485  
(87) N° publication PCT/PCT Publication No.: 1997/020400  
(30) Priorité/Priority: 1995/11/29 (311,102/1995) JP

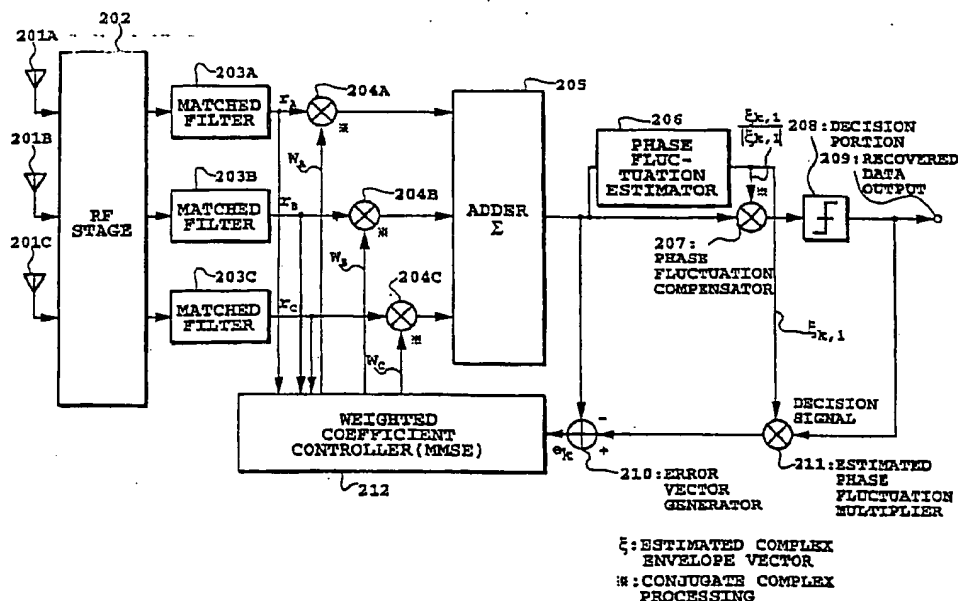
(51) Cl.Int.<sup>6</sup>/Int.Cl.<sup>6</sup> H04B 7/08, H04B 1/69, H04B 7/216

(72) Inventeurs/Inventors:  
TANAKA, Shinya, JP;  
HIGUCHI, Kenichi, JP;  
SAWAHASHI, Mamoru, JP;  
MIKI, Yoshinori, JP;  
ANDO, Hidehiro, JP

(73) Propriétaire/Owner:  
NTT MOBILE COMMUNICATIONS NETWORK INC., JP

(74) Agent BLAKE, CASSELS & GRAYDON LLP

(54) Titre : APPAREIL DE RECEPTION EN DIVERSITE ET PROCEDE DE COMMANDE  
(54) Title: DIVERSITY RECEIVER AND ITS CONTROL METHOD



(57) Abrégé/Abstract

Enabling reception quality to be improved and the capacity in terms of the number of simultaneous users in a cell to be increased, and speeding up the establishment of spreading code synchronization and the convergence of weighted coefficients, by feedback controlling weighted coefficients such that desired signal power to interference power ratio (SIR) becomes maximum. A coherent adaptive diversity configuration is employed to which absolute coherent detection is applicable. Adaptively feeding weighted coefficients back to diversity branches makes it possible to reduce the influence of the interference power from other users, and thus to increase the capacity in terms of the number of simultaneous users in the cell. Furthermore, the direction that provides the maximum received SIR is determined while rotating antennas in a state of having directivity with a predetermined angle range. Setting initial values of the weighted coefficients at values corresponding to that direction enables the weighted coefficients to converge quickly.

Canada

<http://opic.gc.ca> · Ottawa-Hull K1A 0C9 · <http://cipo.gc.ca>

OPIC · CIPQ 191

OPIC



CIPQ

SPECIFICATION

TITLE OF THE INVENTION

5 DIVERSITY RECEIVER AND ITS CONTROL METHOD

TECHNICAL FIELD

The present invention relates to a diversity  
10 receiver and its control method for carrying out  
diversity reception of a data signal transmitted in  
accordance with a direct sequence CDMA (code  
division multiple access) scheme.

Specifically, the present invention is applied  
15 to reception in the code division multiple access  
(CDMA) scheme using a spread spectrum technique, and  
particularly to a mobile communications field using  
a cellular configuration.

More specifically, the present invention is  
20 applied to the field of a diversity receiving  
technique which despreads received signals which are  
input to a plurality of antennas of a diversity  
receiver placed at a base station, multiplies the  
despread signals by appropriate weighted  
25 coefficients, and combines the resultant products.  
In particular, the present invention relates to the

establishment of synchronization between the  
diversity receiver in the base station and a mobile  
station in the base station area, and to the  
procedure of setting initial values of weighted  
5 coefficients.

#### BACKGROUND ART

The DC-CDMA is a scheme for carrying out  
10 communications using a single frequency band shared  
by multiple users, and spreading codes are employed  
to identify the individual users. Here, orthogonal  
codes such as Gold codes are used as the spreading  
codes for the users.

15 In the process of despreading in the receiver,  
the interference signal power from other users are  
reduced by a factor of average processing gain (PG).  
In a mobile communications environment  
(particularly, under reverse link asynchronous  
20 environment), the received signals of the users  
undergo instantaneous fluctuations due to  
independent fading, short term fluctuations and  
distance fluctuations. Accordingly, to satisfy the  
intended reception quality of the users, it is  
25 necessary to carry out the transmission power  
control to keep constant the SIR at the input of the

receiver in the base station, the SIR being defined as the ratio of the received signal power of each user to interference signal power from the other simultaneous users.

5        However, even if the transmission power control is perfect, and hence the SIR at the receiver input is kept constant without fail, the spreading codes are never completely orthogonal under the multipath environment in the mobile communications, and the  
10       interference is unavoidable due to cross-correlation having average power reduced by a factor of processing gain per user.

      Thus, the interference signal power increases with the number of simultaneous users in the same  
15       frequency band. As a result, the capacity in terms of the number of simultaneous users per cell is determined by the receiving quality which in turn is determined by the required quality of the system. To increase the capacity in terms of the number of  
20       simultaneous users, the cross-correlation due to other users must be reduced.

      Interference cancellation techniques are proposed as one of the methods to reduce the cross-correlation from other users. Interference cancellation  
25       techniques that are known include: 1. a multi-user detector that demodulates not only the desired

signal of the intended channel, but also the signals of other simultaneous users received at the receiver input using the spreading code information of the other users; and 2. a single user detector that  
5 minimizes average cross-correlation and noise components from other simultaneous users using the spreading code of only the intended channel. Among these, the single user detector of item 2 corrects a spreading replica code such that the cross-  
10 correlation from other users produced in the process of despreading the desired user signal is reduced through quadrature filters in the receiver.

Another known technique to reduce the cross-correlation from other users to increase the  
15 capacity in terms of the number of simultaneous users, is an adaptive diversity technique as shown in Fig. 1. In Fig. 1, reference numerals 101A-101D each designate an antenna, 102A-102D each designate an RF stage, 103A-103D each designate an  
20 A/D converter, 104A-104D each designate a weighted coefficient multiplier, 105 designates an adder, 106 designates a demodulator, 107 designates a recovered data output terminal, 108 designates a weighted coefficient controller, and 110 designates a  
25 reference signal.

The conventional example as shown in Fig. 1 reduces the interference power from other users by attaching appropriate weights (WA-WD) to input signals to the antennas 101A-101D, and then  
5 combining them.

As another adaptive diversity technique in the DS-CDMA scheme, a method is known in which received signals input to antennas are despread before they are multiplied by appropriate weighted coefficients  
10 to be combined.

In this case, the weighted coefficients to be multiplied are successively updated so that the received SIR becomes maximum. This update enables the weighted coefficients to finally converge to  
15 such a value that will increase the gain in the direction of the incoming waves from a mobile station, but reduce the gain in the direction of incoming interference waves.

This is equivalent to providing the antennas  
20 with adaptive directivity by controlling the values of the weighted coefficients.

The adaptive control, however, is performed on the despread signals. Accordingly, it is necessary to establish the spreading code synchronization  
25 before starting the adaptive control at a base station.

In addition, a period of time required for the weighted coefficients to converge to the values that maximize the received SIR varies depending on values set as initial values of the weighted coefficients  
5 to be multiplied by the despread signals.

Furthermore, the conventional technique does not clearly disclose the procedures from establishing the spreading code synchronization based on the signal sent from the mobile station to setting the  
10 initial values of the weighted coefficients, which procedures are performed by the base station carrying out the adaptive diversity reception of the signals after despreading.

## 15 DISCLOSURE OF THE INVENTION

The conventional adaptive diversity technique as shown in Fig. 1 includes the multipliers 104A-104D and the adder 105 for multiplying the signals of  
20 respective branches by the weighted coefficients, and for summing up the resultant products. And the demodulator 106 demodulates the signals after the summation.

These weighted coefficients WA-WD are controlled  
25 so that the SIR of the summed signal at the adder 105 becomes maximum. However, no research reports

until now have clearly disclosed a method of generating a reference signal for controlling the weighted coefficients, or a method of implementing that.

5        In view of this, a first object of the present invention is to provide a diversity receiver capable of improving the reception quality and increasing the capacity in terms of the number of simultaneous users in the cell by carrying out feedback control  
10 of the weighted coefficients of respective branches such that the ratio of the desired signal power to the interference power (SIR) becomes maximum.

      A second object of the present invention is to provide a control method of an adaptive diversity  
15 receiver which multiplies the despread signal by the weighted coefficients, and combines the resultant products. In particular, the object is to establish the spreading code synchronization and to set appropriate initial values of the weighted  
20 coefficient control.

      According to the first aspect of the present invention, a diversity receiver employing, when receiving a data signal transmitted in accordance with a direct sequence CDMA scheme, correlators for  
25 despread, for respective branches, a plurality of fading received waves, and a plurality of



multipliers for multiplying despread signals output from the correlators by weighted coefficients, the diversity receiver comprises: decision means for recovering the data signal; and weighted coefficient  
5 computing means for using decision error information obtained in response to an output signal and an input signal of the decision means as feedback information for controlling the weighted coefficients.

10 According to the second aspect of the present invention, a diversity receiver for performing diversity reception of a data signal transmitted in accordance with a direct sequence CDMA scheme, the diversity receiver comprises: correlators for  
15 despread, for respective branches, a plurality of fading received waves; a plurality of multipliers for multiplying despread signals output from the correlators by weighted coefficients; an adder for summing up weighted signals output from the  
20 plurality of multipliers; phase compensation means for compensating a signal output from the adder for phase fluctuations of fading received waves; decision means for recovering the data signal from a compensated signal output from the phase  
25 compensation means; subtraction means for computing error vector components corresponding to a

difference between the data signal recovered and the compensated signal; and weighted coefficient generating means for generating the weighting coefficients in response to the phase fluctuations of the fading received signal and the error vector components.

In the diversity receiver, wherein the correlators may be each disposed after RF signal processors provided for respective branches, and carry out correlation detection using a spreading signal sequence replica at a symbol information rate.

According to the third aspect of the present invention, a diversity receiver comprising, for L multipaths, L sets of the correlators, the multipliers, the adder, the phase compensation means and the weighted coefficient generating means, and further comprises: RAKE combining means for combining phase compensated signals output from the phase compensation means corresponding to respective paths; decision means for recovering an incoming data signal by deciding an output of the RAKE combining means; error vector computing means for computing error vector components from an input signal and an output signal of the decision means, or from input signals to the RAKE combining means associated with

respective paths and the output signal from the decision means; and feedback signal computing means for supplying the weighed coefficient generating means for respective paths with feedback decision  
5 information for computing the weighted coefficients from the error vector components and received phase components of individual paths.

Here, the diversity receiver, may further comprise M sets of antennas and RF stages, wherein  
10 the diversity receiver is disposed in common after the RF stages.

According to the fourth aspect of the present invention, a diversity receiver for performing mobile communications with a mobile station using a  
15 direct sequence CDMA scheme that carries out multiple access transmission by spreading a narrowband signal to a wideband signal using a spreading code with a rate higher than that of an information rate, the diversity receiver comprises:  
20 a plurality of receiving antennas for receiving a direct sequence spread signal sent from the mobile station, the receiving antennas being set in a directional state; spreading code synchronization establishing means for performing spreading code  
25 synchronization establishment which corresponds to despread of an input signal to each of the

plurality of receiving antennas; weighted coefficient multiplication means for multiplying weighted coefficients by signals obtained through despread-  
ing by the spreading code synchronization establishing  
5 means; signal combining means for combining signals after multiplications by the weighted coefficient multiplication means; and adaptive diversity  
reception control means for controlling the weighted  
Coefficients such that a received SIR becomes  
10 maximum.

Here, the diversity receiver, may further  
comprise: means for generating forward link  
transmission weighted coefficients from the weighted  
coefficients which are obtained by the adaptive  
15 diversity reception control means and maximize the  
received SIR, the forward link transmission weighted  
coefficients being used when carrying out  
transmission from the diversity receiver to the  
mobile station; and means for correcting the forward  
20 link transmission weighted coefficients using a  
reverse link control signal transmitted from the  
mobile station to the diversity receiver.

According to the fifth aspect of the present  
invention, a diversity receiver control method for  
25 performing mobile communications between a mobile  
station and a diversity receiver using a direct

sequence CDMA scheme that carries out multiple access transmission by spreading a narrowband signal to a wideband signal using a spreading code with a rate higher than that of an information rate, the

5 diversity receiver control method comprises the steps of: receiving with a plurality of receiving antennas a direct sequence spread signal sent from the mobile station, the receiving antennas being set in a directional state; establishing spreading code

10 synchronization which corresponds to despread of an input signal to each of the plurality of receiving antennas; multiplying weighted coefficients by signals obtained through despread in the step of establishing spreading code

15 synchronization; combining signals after multiplications in the step of multiplying weighted coefficients; and controlling adaptive diversity reception by controlling the weighted coefficients such that a received SIR becomes maximum.

20 In the diversity receiver control method, wherein the step of receiving with a plurality of receiving antennas may comprise a step of receiving the direct sequence spread signal sent from the mobile station with the antennas being set in non-

25 directional state; and the step of controlling adaptive diversity reception comprises a step of

setting initial values of the weighted coefficients at values corresponding to the non-directional state.

- In the diversity receiver control method,
- 5 wherein the step of receiving with a plurality of receiving antennas may comprise a step of receiving the direct sequence spread signal sent from the mobile station with the antennas being set in non-directional state; and the step of controlling
- 10 adaptive diversity reception comprises a step of setting initial values of the weighted coefficients at values obtained when the diversity receiver turns its gain to one direction.

- In the diversity receiver control method,
- 15 wherein the step of receiving with a plurality of receiving antennas may comprise a step of receiving the direct sequence spread signal sent from the mobile station with the antennas being set in a state in which the diversity receiver has
- 20 directivity in one direction with a predetermined angle range, and sets the directivity which provides maximum received SIR by measuring the received SIR one or more times while rotating the directivity of the antennas at predetermined intervals after the
- 25 establishment of the spreading code synchronization; and the step of controlling adaptive diversity

reception comprises a step of setting initial values of the weighted coefficients at values obtained when the diversity receiver turns its gain to the direction providing the maximum received SIR.

5        Here, the diversity receiver control method, may further comprise the steps of: generating forward link transmission weighted coefficients from the weighted coefficients which are obtained in the step of controlling adaptive diversity reception, and  
10       maximize the received SIR, the forward link transmission weighted coefficients being used when carrying out transmission from the diversity receiver to the mobile station; and correcting the forward link transmission weighted coefficients  
15       using a reverse link control signal transmitted from the mobile station to the diversity receiver.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20       Fig. 1 is a block diagram showing a configuration of a conventional adaptive diversity technique;

      Fig. 2 is a block diagram showing a first embodiment of an adaptive diversity system in  
25       accordance with the present invention;

Fig. 3 is a diagram illustrating a structure of a frame applicable to the adaptive diversity system in accordance with the present invention;

Fig. 4 is a diagram illustrating a phase error compensation method in the embodiments in accordance with the present invention;

Fig. 5 is a block diagram showing a second embodiment in accordance with the present invention;

Fig. 6 is a block diagram showing a third embodiment in accordance with the present invention;

Fig. 7 is a diagram illustrating procedures for establishing spreading code synchronization, and adaptive control of weighted coefficients in a fourth embodiment in accordance with the present invention;

Fig. 8 is a diagram illustrating procedures for establishing the spreading code synchronization, and the adaptive control of weighted coefficients in the fourth embodiment in accordance with the present invention;

Fig. 9 is a block diagram showing a fifth embodiment of an adaptive diversity system in accordance with the present invention; and

Fig. 10 is a diagram illustrating procedures for establishing the spreading code synchronization, and the adaptive control of weighted coefficients in the



fifth embodiment in accordance with the present invention.

#### BEST MODE FOR CARRYING OUT THE INVENTION

5

In the following example which will be described with reference to the accompanying drawings as an embodiment to which the present invention is applied, we assume that it has a coherent adaptive  
10 diversity configuration to which absolute coherent detection can be applied. In this configuration, phase fluctuation compensation against fading is carried out by estimating phase fluctuations using known pilot symbols. Then, weighted coefficients  
15 are controlled such that an error vector becomes minimum (that is, a received SIR becomes maximum), where the error vector is defined as a difference between the signal whose phase fluctuations due to fading are compensated and a signal obtained by  
20 decision.

Thus, in a diversity receiver in accordance with the present invention, the maximum SIR can be obtained for each symbol by minimizing the error vector obtained by decision feedback. In other  
25 words, the effect of interference power from other simultaneous users can be reduced by the adaptive

feedback control of the weighted coefficients of respective diversity branches. As a result, the capacity in terms of the number of simultaneous users in a cell can be increased.

5        More specifically, the embodiments in accordance with the present invention employ a CDMA (Code Division Multiple Access) scheme that carries out multiple access transmission by spreading information into a wideband signal using spreading  
10 codes with a rate higher than an information rate. A transmitting end forms a frame by periodically inserting a known pilot signal into an information data signal at several symbol intervals, and expands bandwidth using a spreading code with a period equal  
15 to an information symbol period.

On the other hand, a receiver which receives N-multipath signals comprises M antennas and RF receiving circuits, where M is equal to or greater than two; correlators each for obtaining correlation  
20 using a spreading code sequence replica in synchronism with a spreading code sequence in a desired received signal associated with each antenna; M weighted coefficient multipliers for multiplying the output of each correlator by a  
25 complex weighted coefficients; an adder for summing up outputs of the weighted coefficient multipliers;

a phase error estimation compensator for estimating received phase error of each information signal by interpolation of the received phase of the pilot signal of a known pattern which is included in the frame in the output sequence from the adder, thus to compensate the received phase error; a decision portion for making decision of the signal which has undergone the phase error compensation signal by symbol by the phase error estimation compensator; an error vector generator for generating the error vector between a received signal vector after the phase error compensation and a signal vector after the decision; a phase fluctuation estimation multiplier for multiplying the error vector generated by the error vector generator by the phase fluctuation estimate estimated by the phase error estimation compensator; and a complex weighted coefficient controller for obtaining complex weighted coefficients of the individual antennas such that the mean square error of the multiplier becomes minimum.

The adaptive diversity block of the receiver described above comprises L correlators for the multipaths to be RAKE combined, where L is the number of multipaths; L weighted coefficient multipliers; L adders and L phase error estimation

compensators. It further comprises a RAKE combiner for summing up the signals output from the L phase error estimation compensators after multiplying them by estimated complex envelopes used as weighted  
5 coefficients; a decision portion for making a decision of the output signal from the RAKE combiner; an error vector generator for generating an error vector, that is, the difference between a received signal vector after the phase error  
10 compensation and a signal vector after the decision; a phase fluctuation estimation multiplier for multiplying the error vector generated by the error vector generator by the phase fluctuation estimates estimated by the phase error estimation  
15 compensators; and complex weighted coefficient controllers for obtaining the complex weighted coefficients of the individual branches such that the mean square error of the multiplier becomes minimum.

20 According to the embodiments to which the present invention is applied: 1. the weighted coefficients are decided for respective branches by the feedback control that minimizes the error vector; and 2. the weighting processing is carried  
25 out on the information symbols that have been despread. In other words, it performs a baseband

processing, so to speak. Thus, the hardware configuration is much more simplified than that of the conventional system which carries out weighting at the stage previous to the despreading stage which  
5 requires the processing at a chip rate.

The embodiments in accordance with the present invention will now be described in more detail referring the accompanying drawings.

10 EMBODIMENT 1

Fig. 2 shows an embodiment of a diversity receiver to which the present invention is applied. In Fig. 2, the reference numerals 201A-201C each designate an antenna, 202 designates an RF stage,  
15 203A-203C each designate a matched filter, 204A-204C each designate a weighted coefficient multiplier, 205 designates an adder, 206 designates a phase fluctuation estimator, 207 designates a phase fluctuation compensator, 208 designates a decision  
20 portion, 209 designates a recovered data output terminal, 210 designates a error vector generator,  $e_k$  designates an error vector, 211 designates an estimated phase fluctuation multiplier, and 212 designates a weighted coefficient controller. In  
25 addition, the \* mark in this figure indicates a conjugate complex processing. In this

specification, we will represent the vector signals by normal type rather than by bold type for the convenience of typing.

The diversity receiver as shown in Fig. 2 will now be described assuming that it is used as a receiver of a base station. Besides, it is assumed that the antenna of the base station is much taller than antennas of mobile stations. In this case, the incoming signals to the base station from the mobile stations in the cell arrive from various directions to be received by the base station. The received signals from other users become interference signals to a desired received signal on the intended channel. In the DS-CDMA system, the correlations between the spreading codes of the users in the despread process are small, and the signal power of the other users after the despread is reduced on average by a factor of the processing gain. The residual interference power, however, will degrade the received quality because it increases with an increase in the number of the simultaneous users.

The incoming waves from the mobile stations in the cell to the antenna of the base station arrive from random directions. Accordingly, the signal to interference power ratio (SIR) of the desired received signal can be increased by maximizing the

combined gain of the multiple antennas for the  
desired channel, and by setting the received  
directions of the interference stations at the null  
point for the interference signal. The received  
5 signals from M antennas (only three antennas 201A-  
201C are depicted in Fig. 2) have delays determined  
by spaces between antennas, incident angles, and the  
frequency of a carrier. When the spaces between  
antennas are small, the amplitude fluctuations and  
10 phase fluctuations due to fading transmission paths  
can be handled as the same for respective antennas.

The incoming RF signals obtained through the  
antennas 201A-201C, are each amplified and frequency  
converted by the RF stage 202, thus being converted  
15 into baseband signals. Subsequently, the baseband  
signals are each despread by the matched filters  
203A-203C using the spreading code replica of the  
intended channel (specified channel). The despread  
signals are output as rA, rB and rC, and are  
20 multiplied by the complex weighted coefficients  
associated with the branches by the multipliers  
204A-204C. The complex weighted coefficients  
undergo conjugate complex processing (represented by  
the \* mark) before multiplied by the multipliers  
25 204A-204C. The M (M=3, in this case) signals

regard to the binary PSK (BPSK), the decision is made whether +1 or -1. Generally speaking, when the SIR is small owing to large interference power, the phase error increases between the phase fluctuation compensated signal vector and the decided signal vector. Considering this, the error vector  $e_k$  representing the phase error is output from the error vector generator (subtractor) 210. Then, the weighted coefficients are controlled in the procedure which will be described in detail below such that the error vector  $e_k$  becomes minimum.

The error vector  $e_k$  is generated by multiplying the decided signal by an estimated phase fluctuation amount output from the phase fluctuation estimator 206 by the estimated phase fluctuation multiplier 211, and by obtaining the difference between the product and the signal before the phase fluctuation compensation. The weighted coefficient controller 212 controls the weighted coefficients using the error vector  $e_k$ , and updates the weighted coefficients for individual symbols using the multiplication output signal. As the update algorithm, LMS (Least Mean Square) algorithm, or RLS (Recursive Least Square) algorithm can be used. The weighted coefficient update using the LMS algorithm can be performed as follows:



$$(1) \ w_k(m+1) = w_k(m) + \mu \cdot r(m) \cdot e_k^*(m)$$

where,  $w_k(m)$  is a weighted coefficient vector of a user  $k$  in the time series  $m$ ,  $r(m)$  is a despread signal vector (outputs of the matched filters),  
 5  $e_k(m)$  is the error vector of the user  $k$ , and  $\mu$  is a fixed value for determining the averaging time.

The diversity receiver to which the present invention is applied can use any types of spreading codes regardless of their types because it performs  
 10 weighted coefficient control on the symbols after the despreading.

#### EMBODIMENT 2

Fig. 5 is block diagram showing a configuration  
 15 of an embodiment having a RAKE function for multipath signals. The configuration in Fig. 5 comprises antennas 501A-501C; an RF stage 502; an A/D converter 503; delay circuits 518A/518C; baseband processors 504-1 - 504-L for first to L-th  
 20 path signals, each of which includes matched filters 505A-505C, weighted coefficient multipliers 506A-506C, an adder 507, a level adjuster 508, a phase fluctuation estimator 509, a phase fluctuation compensator 510, a RAKE combiner 511, a decision  
 25 portion 512, a recovered data output 513, an error

vector generator 515, an estimated phase fluctuation multiplier 516, and a weighted coefficient controller 517.

If the height of the received antenna is  
5 affected by surrounding buildings, the radio waves from mobile stations are received through multipaths. To handle the multipath signals, this embodiment has the matched filters 505A-505C, the weighted coefficient multipliers 506A-506C, the  
10 adder 507, the phase fluctuation estimator 509, the phase fluctuation compensator 510, the error vector generator 515, the estimated phase fluctuation multiplier 516, and the weighted coefficient controller 517, all of which are needed by the  
15 number of the multipaths for each user. Here, the following processes are similar to those of the embodiment as shown in Fig. 2 (the single path case): despreading by the matched filters, multiplying the signals of respective branches by  
20 the complex weighted coefficients, followed by summing up the products; carrying out the phase fluctuation estimation using the pilot symbols in the frame (see, Fig. 3); and performing the phase fluctuation compensation in accordance with the  
25 positions of the information symbols. Only, it is necessary for the multipath signals to be despread

at the received spreading code phases corresponding to the transmission delay times of respective paths to achieve the RAKE combining.

The phase fluctuation compensated signals of  
5 respective paths undergo maximal-ratio combining by the RAKE combiner 511 such that power weighting is implemented using the complex envelopes of the paths. The RAKE combined signal of each user is fed to the decision portion 512 which decides the signal  
10 to recover the transmitted data.

The error vector  $e_k$  output from the error vector generators 515 and fed to the weighted coefficient controllers 517 can be obtained by multiplying the decided data output from the decision portion 512 by  
15 the estimated phase fluctuations output from the phase fluctuation estimators 509 through the estimated phase fluctuation multipliers 516, and by obtaining differences between the products and the signals before the phase fluctuation compensation.

20

### EMBODIMENT 3

Fig. 6 is a block diagram showing the entire configuration of a receiver when a diversity receiver, to which the present invention is applied,  
25 is used as a base station receiver. Since the present embodiment employs the baseband digital

signal processing to perform the weighting control of respective branches, RF stages (including IF circuits) 602A-602C and A/D converters 603A-603C of respective branches can be used in common as shown  
5 in Fig. 6. Thus, the A/D converter outputs of the branches are input to baseband receiving portions 604-1 - 604-P for carrying out the weighting control, combining and demodulation for each user. The baseband receiving portions 604-1 - 604-P each  
10 correspond to the embodiment 2 as shown in Fig. 5.

With this arrangement, it is possible to reduce the size and cost of the device because the diversity reception can be implemented by the baseband digital signal processing.

15 Next, a procedure will be described for starting adaptive control of the weighted coefficients in a base station in the case where a mobile station is present in the area of the base station, and the base station establishes the spreading code  
20 synchronization to a direct sequence signal transmitted from the mobile station.

#### EMBODIMENT 4

Fig. 2 is a block diagram showing the  
25 configuration of a diversity receiver in a base station in the present embodiment. The diversity

receiver in the base station has a plurality of receiving antennas, establishes spreading code synchronization by matched filters prepared for respective antennas, and despreads the signal from the mobile station. The diversity reception can be achieved by multiplying the despread signals associated with antennas by appropriate weighted coefficients, and by combining the products by an adder.

10 This embodiment employs a coherent adaptive diversity configuration to which the absolute coherent detection can be applied. More specifically, this embodiment comprises a phase fluctuation estimator for estimating the phase fluctuation due to fading, and a phase fluctuation compensator for carrying out compensation. The phase fluctuation estimator estimates the received phase errors of information signals by interpolating the received phases of known pilot symbols. The weighted coefficients of individual branches are determined by the weighted coefficient controller. The MMSE decision feedback control is achieved by multiplying the decided signal output from the decision portion 208 by the estimated phase fluctuations output from the phase fluctuation estimator 206 by the estimated phase fluctuation

multiplier 211, and by minimizing the error vector which is the difference between the product signals and the signals before the phase fluctuation compensation. Finally, the SIR of the received  
5 signal converges to a value which maximizes the SIR.

Figs. 7 and 8 illustrate the procedures for carrying out the adaptive diversity reception, in which a base station 701 of this embodiment establishes the spreading code synchronization based  
10 on the signal sent from a mobile station 702, and sets the initial values of the weighted coefficients.

As shown in Fig. 7, the signal sent out of the mobile station 702 arrives at the base station 701  
15 from all directions of 360-degrees. Thus, the base station 701 has its antenna set at non-directional state to receive the signal to establish the synchronization of the spreading code, thereby establishing the spreading code synchronization.  
20 Subsequently, the adaptive control of the weighted coefficients are carried out for the despread signal.

The direction of the incoming wave, however, cannot be detected at the time when the  
25 synchronization of the spreading code is established. Thus, the initial values of the

weighted coefficients are first set at values associated with a particular direction with regard to the diversity receiver (703). Then, the values of the weighted coefficients converge to such values  
5 that will maximize the received SIR (704).

Alternatively, as shown in Fig. 8, the initial values of the weighted coefficients are first set at the non-directional state (803). Then, the values of the weighted coefficients converge to such values  
10 that will maximize the received SIR (804).

#### EMBODIMENT 5

Fig. 9 shows a configuration of a diversity receiver in a base station in the present  
15 embodiment.

The configuration of the diversity receiver in the base station comprises, in addition to that as described in the embodiment 4 in connection with Fig. 2, an arrangement which has the received signal  
20 before the phase fluctuation compensation sent to a received SIR measurer 914, and which enables an antenna directivity controller 913 to control the directivity of the antenna in response to the measured SIR through antenna directivity generators  
25 915A, 915B and 915C.

Fig. 10 illustrates the procedures for carrying out the adaptive diversity reception, in which a base station 1001 of this embodiment establishes the spreading code synchronization with the signal sent from a mobile station 1002, and sets the initial values of the weighted coefficients.

The base station 1001 has the antenna set at the directional state with a certain angle, and rotates its direction at a predetermined interval to receive the signal from the mobile station 1002, thereby establishing the spreading code synchronization. The spreading code synchronization is carried out in each direction of the antenna, and the signal level (SIR) is detected in that direction, thereby directing the antenna in the direction which achieves the maximum received SIR.

Subsequently, the adaptive control of the weighted coefficients of the despread signal is started. In this case, since it is known that the incoming wave arrives from the direction close to that of the antenna, the initial values of the weighted coefficients can be set at values corresponding to the direction of the antenna to start the adaptive control (1003). The weighted coefficients converge to such values that will maximize the SIR (1004).



As described above, the present invention minimizes the error vector by decision feedback so that the weighted coefficients of the individual diversity branches are controlled to maximize the SIR for each symbol. As a result, the effect of the interference power from other simultaneous users can be reduced. This makes it possible to increase the capacity in terms of the number of simultaneous users in the cell.

10 Furthermore, according to the present invention, the synchronization of the spreading code and the adaptive control of the weighted coefficients, which are necessary for implementing the adaptive diversity reception of the signals from the mobile stations, can be started independently of the direction of the incoming wave. This enables the synchronization of the spreading code to be established faster.

Moreover, since the SIR increases when the antenna points to the direction of the incoming wave, the spreading code synchronization can be established even under the environment of abundant interference noise. The weighted coefficient control following establishment of the spreading code synchronization can set its initial value close to those corresponding to the incoming direction of

the wave because it is nearly known. Thus, the convergent time of the weighted coefficients can be shortened.

WHAT IS CLAIMED IS:

1. A diversity receiver for performing diversity reception of a data signal transmitted in accordance with a direct sequence CDMA scheme, said diversity receiver comprising:
  - 5 a plurality of correlators for despreading, for respective branches, a plurality of fading received waves;  
a plurality of multipliers for multiplying despread signals output from respective ones of said correlators by weighted coefficients;
  - 10 an adder for summing up weighted signals output from said plurality of multipliers;  
a phase fluctuation estimation means for estimating phase fluctuations of fading received waves with respect to a signal output from said adder;
  - 15 phase fluctuation compensating means for compensating said signal output from said adder for phase fluctuations of fading received waves by using said estimated phase fluctuations;  
deciding and recovering means for recovering said  
20 transmitted data signal from a phase compensated signal output from said phase fluctuation compensating means;  
estimated phase fluctuation multiplying means for multiplying said recovered data signal by an output signal of said phase fluctuation estimating means;
  - 25 subtraction means for generating error vector components by subtracting said output of said adder from said output of said estimated phase fluctuation multiplying means; and

weighted coefficient controlling means for generating said weighted coefficients in response to said outputs from said correlators and said error vector components.

5 2. A diversity receiver as claimed in claim 1, wherein said correlators are each disposed after RF signal processors provided for respective branches, and carry out correlation detection using a spreading signal sequence replica at a symbol information rate.

10

3. A diversity receiver for performing diversity reception of a data signal transmitted in accordance with a direct sequence CDMA scheme, said diversity receiver comprising:

15 for individual paths of L multipaths, a plurality of correlators for despreading, for respective branches, a plurality of fading received waves;

a plurality of multipliers for multiplying despread signals output from respective ones of said correlators by weighted coefficients;

20 an adder for summing up weighted signals output from said plurality of multipliers;

a phase fluctuation estimating means for estimating phase fluctuations of fading received waves with respect to a signal output from said adder;

25 phase fluctuation compensating means for compensating said signal output from said adder for phase fluctuations of fading received waves by using said estimated phase fluctuations;

deciding and recovering means for recovering said transmitted data signal from a phase compensated signal output from said phase fluctuation compensating means; and said diversity receiver further comprising:

5       RAKE combining means for combining phase compensated signals output from said phase fluctuation compensating means corresponding to respective paths;

      decision means for recovering the transmitted data signal by deciding an output of said RAKE combining means;

10       means for inputting said recovered data signal into estimated phase fluctuation multiplying means which corresponds to each path and which multiplies said recovered data signal by an output signal of said phase fluctuation estimating means.

15

4.    The diversity receiver as claimed in claim 3, further comprising M sets of antennas and RF stages, wherein said diversity receiver in claim 3 is disposed in common after said RF stages.

20

5.    A diversity receiver as claimed in claim 1, further comprising:

      a plurality of antenna directivity generating units for adding, for respective branches, antenna directivity to a  
25   plurality of inputted fading received waves;

      a received SIR measuring unit for measuring an SIR of an output signal of said adder; and

antenna directivity controlling means for controlling said antenna directivity generating units such that a received SIR becomes maximum in response to measured results of said received SIR measuring unit;

5        wherein outputs of said plurality of antenna directivity generating units are input into said plurality of correlators, respectively.

6.        The diversity receiver as claimed in claim 5, further  
10        comprising:

          adaptive diversity reception control means for controlling said weighted coefficients such that a received SIR becomes maximum;

          means for generating forward link transmission weighted  
15        coefficients from said weighted coefficients which are obtained by said adaptive diversity reception control means and maximize the received SIR, said forward link transmission weighted coefficients being used when carrying out transmission from said diversity receiver to said mobile  
20        station; and

          means for correcting said forward link transmission weighted coefficients using a reverse link control signal transmitted from said mobile station to said diversity receiver.

25

7.        A diversity receiver control method for performing mobile communications between a mobile station and a diversity receiver using a direct sequence CDMA scheme that carries out multiple access transmission by spreading a  
30        narrowband signal to a wideband signal using a spreading code with a rate higher than that of an information rate,

said diversity receiver control method comprising the steps of:

receiving with a plurality of receiving antennas a direct sequence spread signal sent from said mobile station,  
5 said receiving antennas being set in a directional state;

establishing spreading code synchronization which corresponds to despreading of an input signal to each of said plurality of receiving antennas;

10 multiplying weighted coefficients by signals obtained through despreading in said step of establishing spreading code synchronization;

combining signals after multiplications in said step of multiplying weighted coefficients; and

15 controlling adaptive diversity reception by controlling said weighted coefficients such that a received SIR becomes maximum.

8. The diversity receiver control method as claimed in claim 7, wherein said step of receiving with a plurality of  
20 receiving antennas comprises a step of receiving the direct sequence spread signal sent from said mobile station with the antennas being set in non-directional state; and

said step of controlling adaptive diversity reception comprises a step of setting initial values of said weighted  
25 coefficients at values corresponding to the non-directional state.

9. The diversity receiver control method as claimed in claim 7, wherein said step of receiving with a plurality of receiving antennas comprises a step of receiving the direct sequence spread signal sent from said mobile station with  
5 the antennas being set in non-directional state; and

said step of controlling adaptive diversity reception comprises a step of setting initial values of said weighted coefficients at values obtained when said diversity receiver turns its gain to one direction.

10

10. The diversity receiver control method as claimed in claim 7, wherein said step of receiving with a plurality of receiving antennas comprises a step of receiving the direct sequence spread signal sent from said mobile station with  
15 the antennas being set in a state in which said diversity receiver has directivity in one direction with a predetermined angle range, and sets the directivity which provides maximum received SIR by measuring the received SIR one or more times while rotation the directivity of the  
20 antennas at predetermined intervals after the establishment of said spreading code synchronization; and

said step of controlling adaptive diversity reception comprises a step of setting initial values of weighted coefficients at values obtained when said diversity receiver  
25 turns its gain to the direction providing the maximum received SIR.

11. The diversity receiver control method as claimed in claim 7, further comprising the steps of:



generating forward link transmission weighted  
coefficients from said weighted coefficients which are  
obtained in said step of controlling adaptive diversity  
reception, and maximize the received SIR, said forward link  
5 transmission weighted coefficients being used when carrying  
out transmission from said diversity receiver to said mobile  
station; and

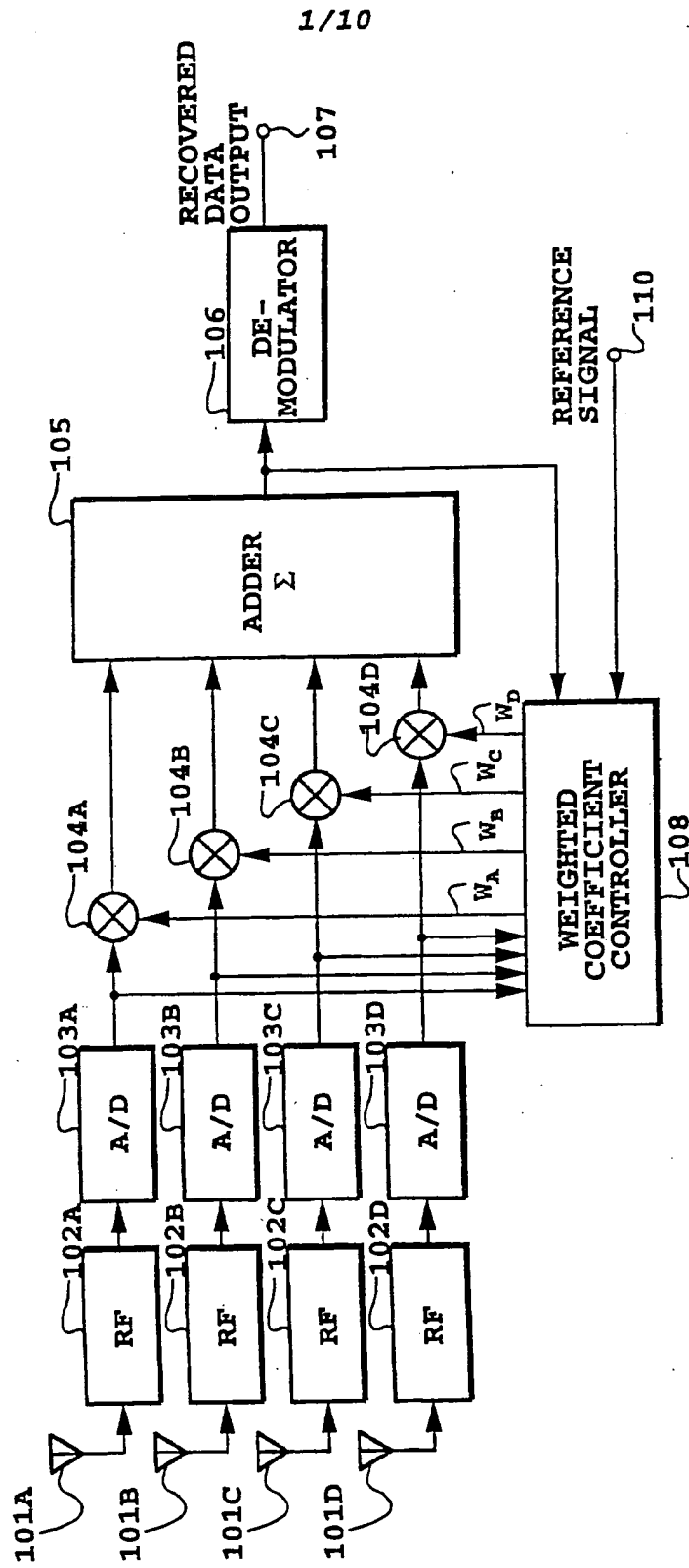
correcting said forward link transmission weighted  
coefficients using a reverse link control signal transmitted  
10 from said mobile station to said diversity receiver.

15

20

25

20696571.2



**FIG. 1**  
PRIOR ART

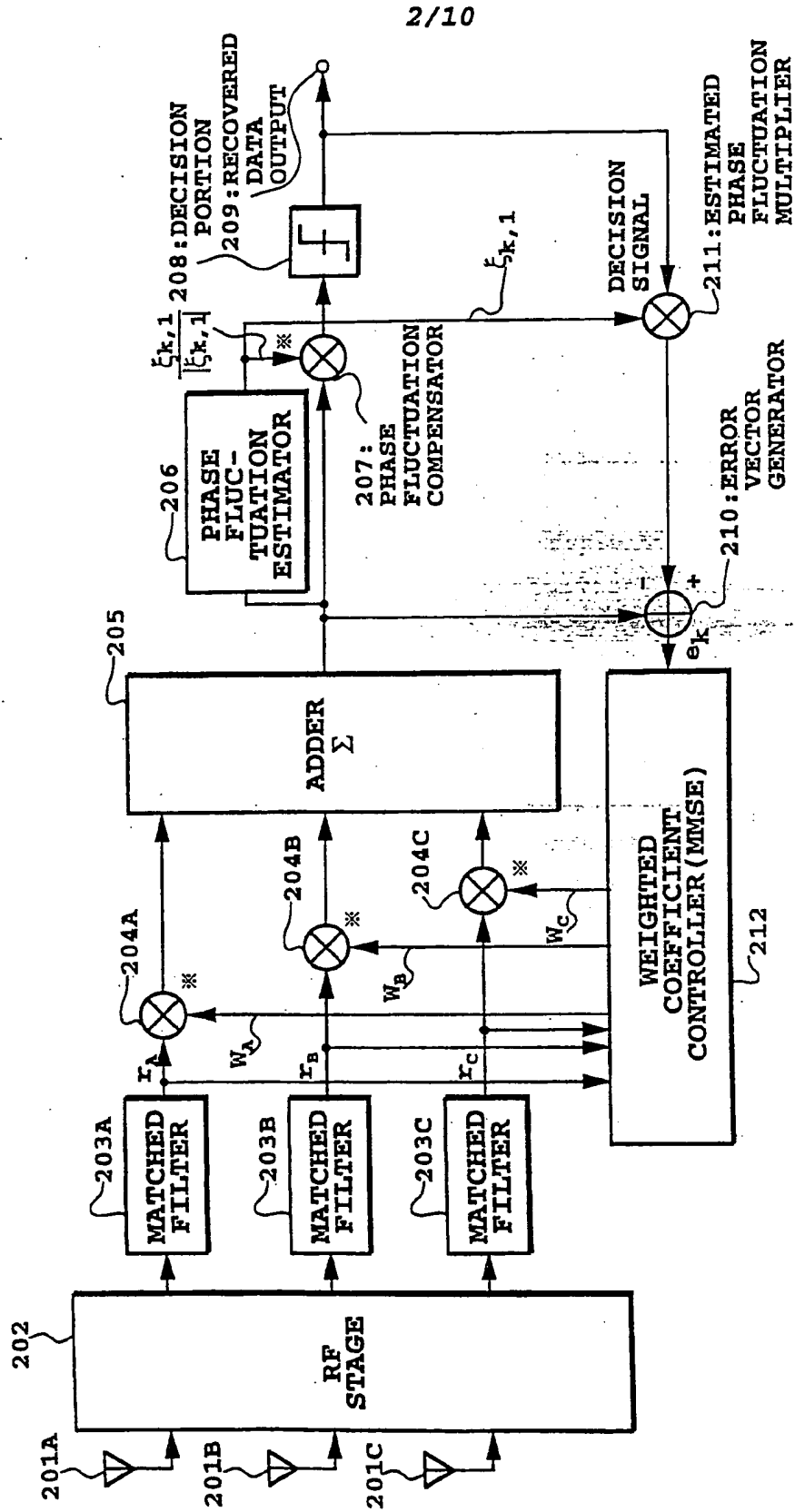
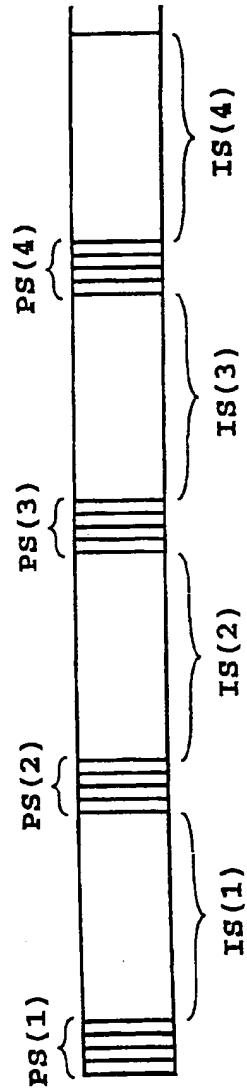


FIG. 2

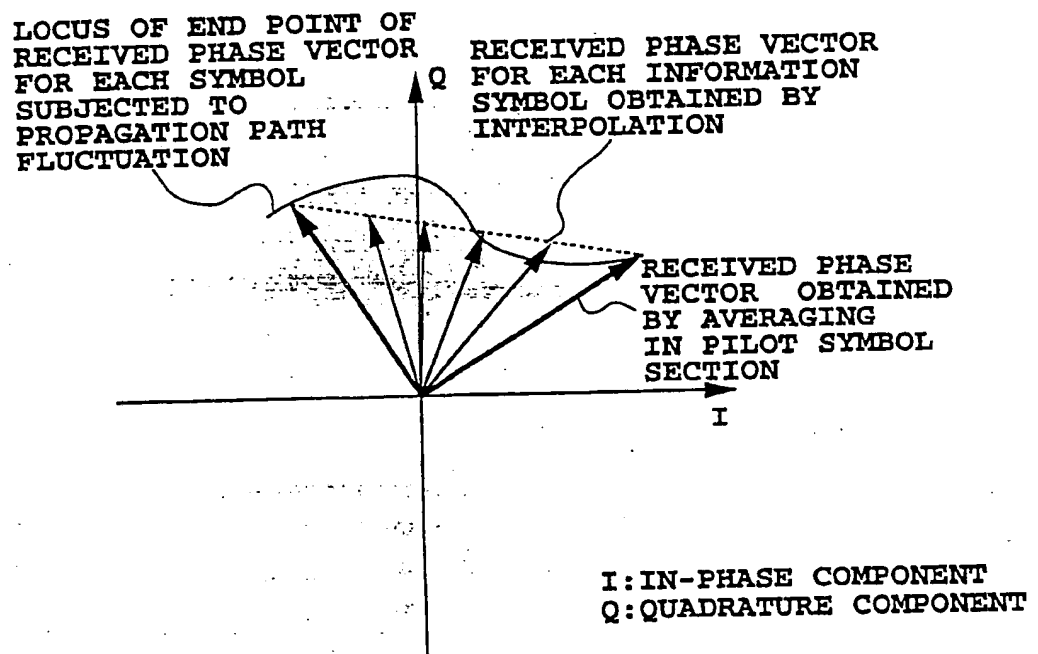
3/10



PS:PILOT SYMBOLS  
IS:INFORMATION SYMBOLS

**FIG.3**

4/10



**FIG.4**

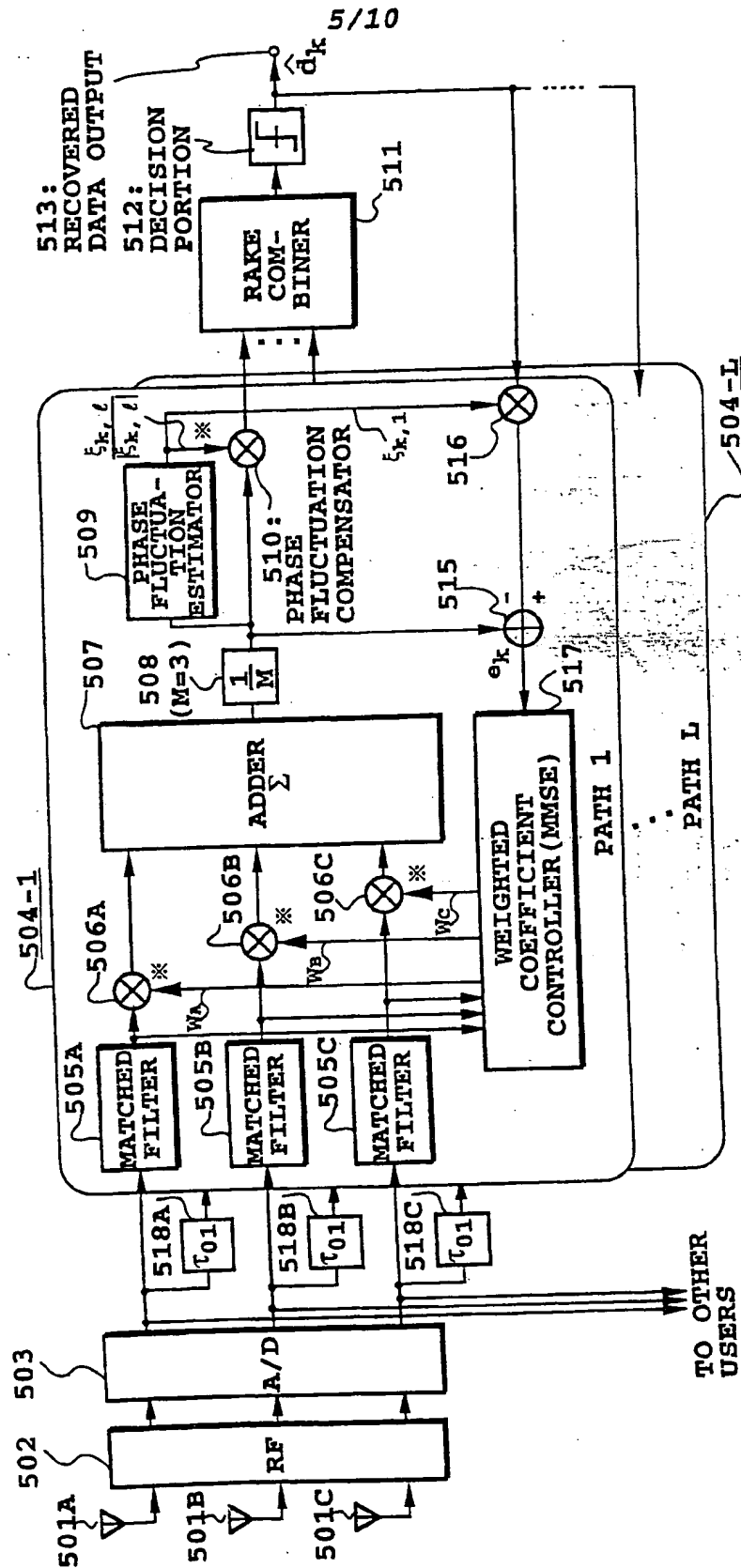


FIG. 5

6/10

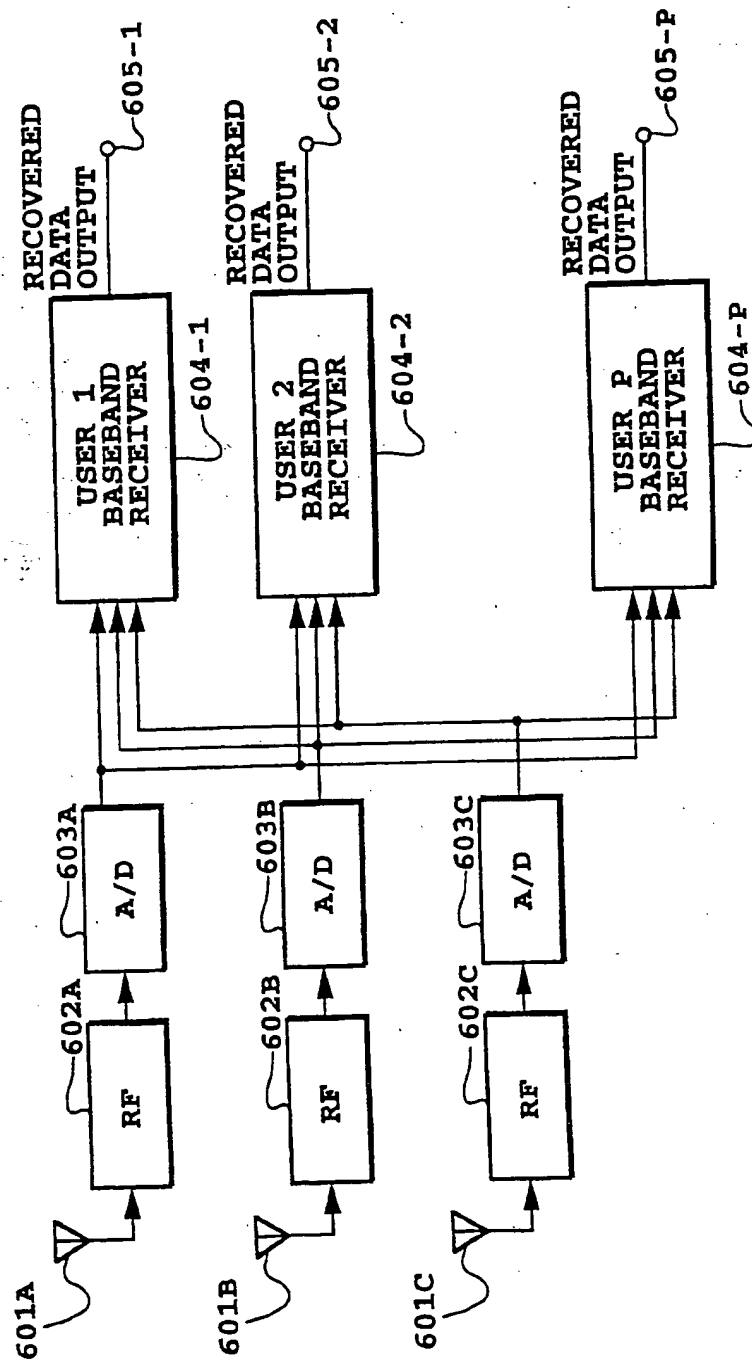


FIG. 6

7/10

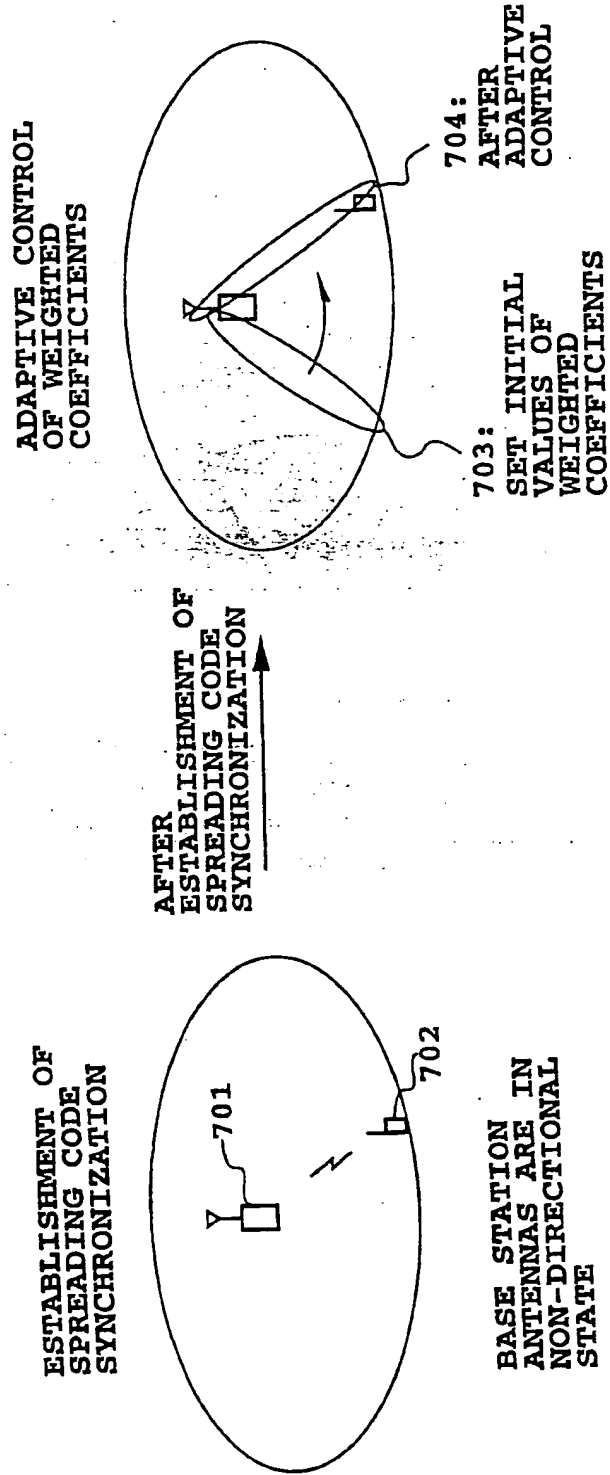


FIG.7



8/10

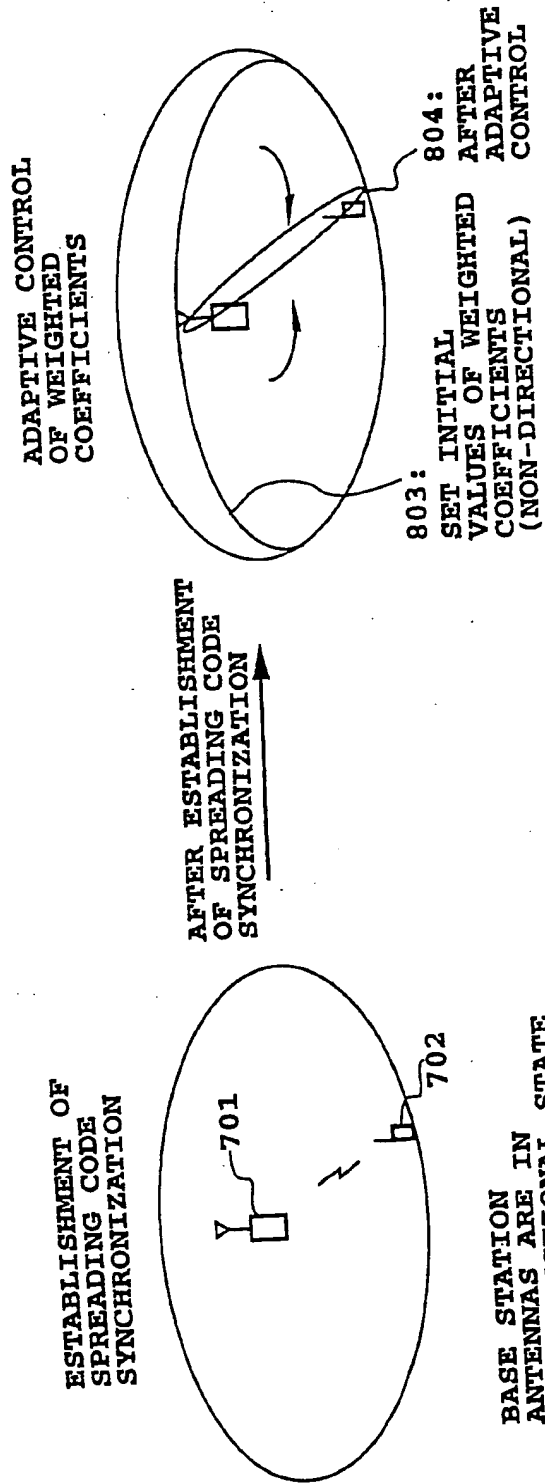


FIG.8

9/10

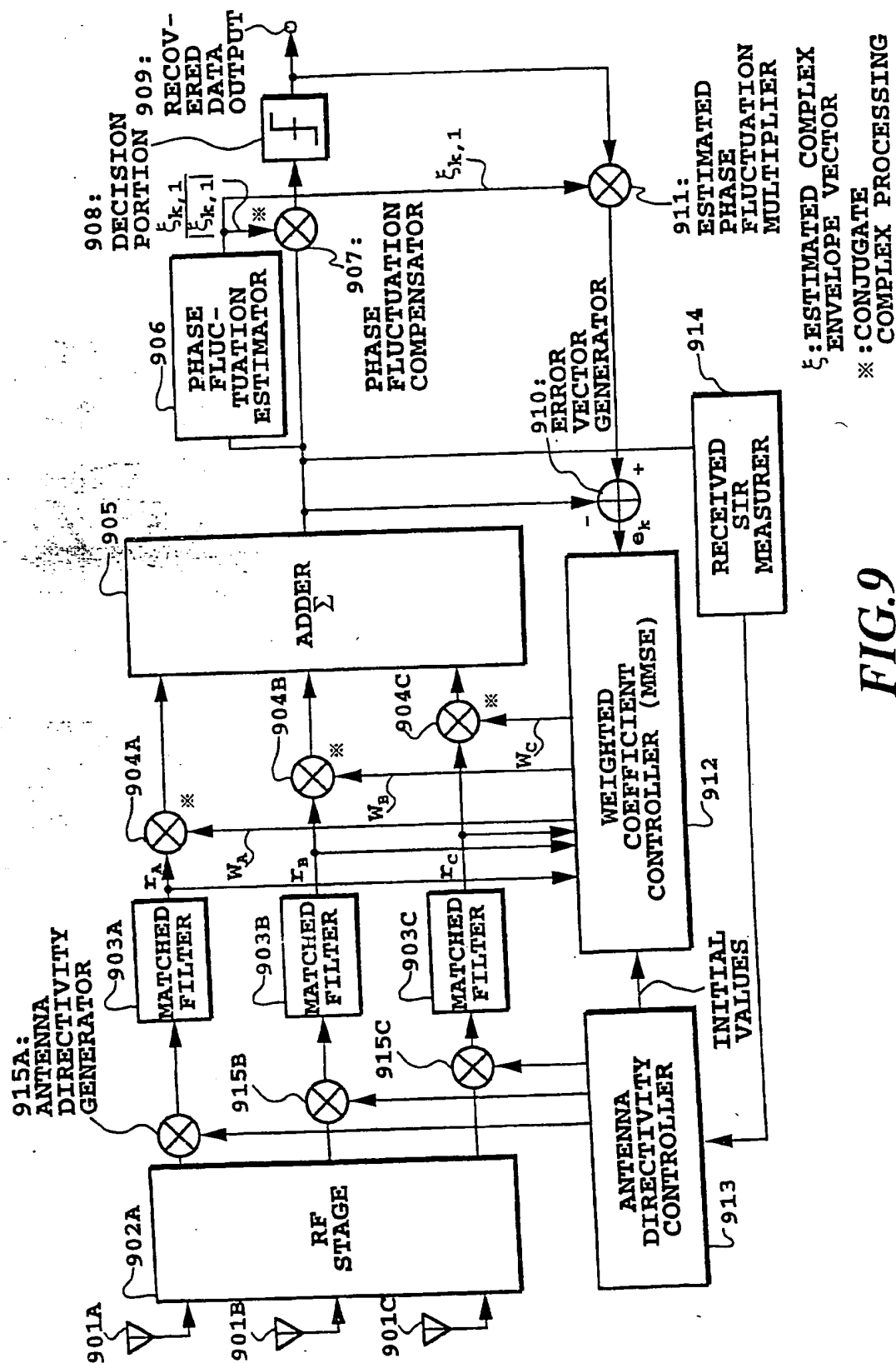


FIG.9

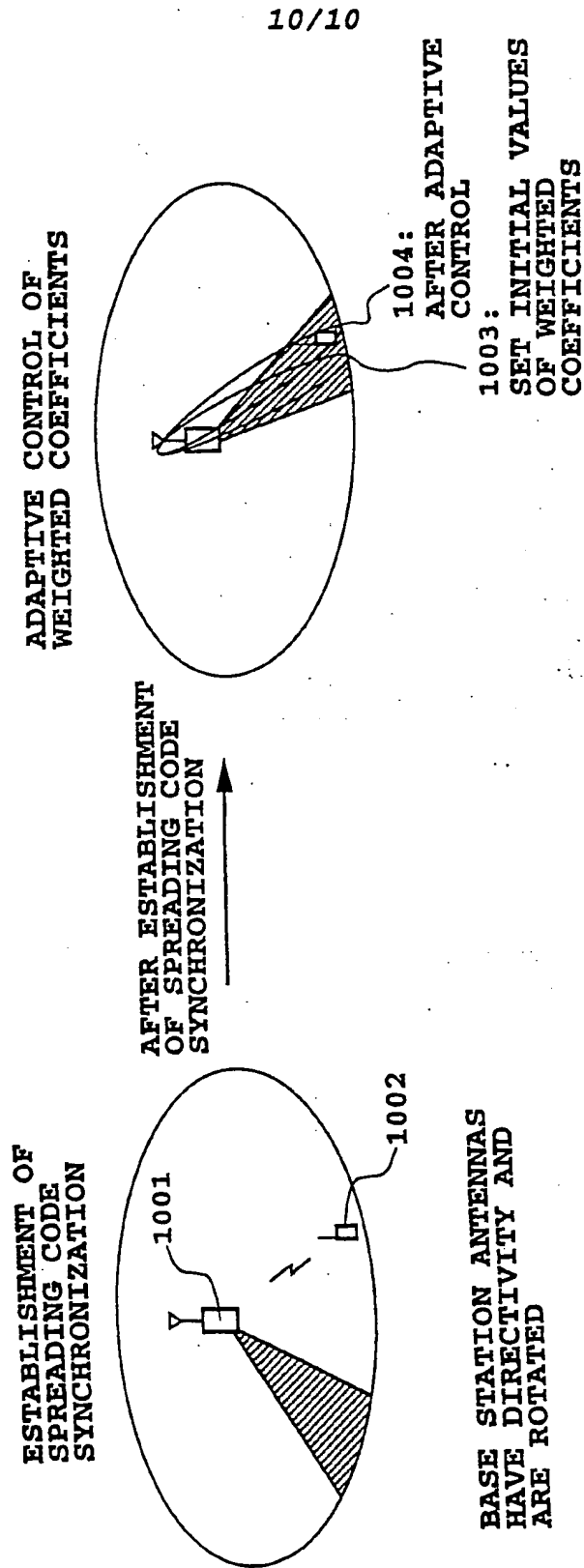


FIG.10